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AN ANALYSIS OF WIRE-CUT PARAMETERS IN ELECTRIC-DISCHARGE OF TITANIUM ALLOYS

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ABSTRACT

The present paper, focuses on wire electric dis-charge machine of titanium alloys. It can be considered as an attempt to develop two models of response variables, they are; the operating rate, the surface-roughness, and the rate of material removing, In the wire electric dis-charge machine process using the response surface methodology. The pilot plan is based on Minitab 18, and the analysis convey the major six parameters. ANOVA was applied to determine the importance of the advanced model, the test results confirm the validity and suitability of the advanced RSM-model. Lastly, the optimum parameter settings is improved.

KEYWORDS: Wire Electric Dis-Charge Machine, Titanium & MR, SR & RSM

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Original Article

INTRODUCTION

There are various materials from complex disciplines in the field of engineering branches, especially mechanical engineering where the path of mechanical engineering study includes the characteristics of materials of various types, especially those that contain high hardness and excellent strength and resistance to the impact of weight and light weight and excellent resistance to corrosion and much more. The deep study for such materials, requires care attention. Examples for such materials are, composites of alloy-ceramic, alloy-materials and/or hard-materials such as Tungsten-Carbide, Titanium, etc., all have evolved to meet the daily life demands. One of the most important material used in mechanical engineering is the Titanium due to its highest-strength regarding to the weighted ratio compared to all other metals. Due to the hardness of titanium compared to other materials, the feeding rate of the milling machine will have a thickness of about half the thickness of the feeding rate, which makes it difficult to operate the machine during preparation in comparison with aluminum or steel. Another reason is that the tool which cuts them generates much more heat than aluminum or steel when compared with titanium. This heat will also work on the heat treatment of titanium making it more difficult than the carbide cutting tools, thus breaking the tool. We would like to point out that in its solid state, titanium hardness will be similar to stainless steel, and all these reasons provide a platform for the current research to use titanium as a material that can be manufactured by the process of cutting vacuum wire. Kumar, Kumar, Kumar **[1]** focuses on the process of manufacturing of electrical wires. In this research, the researchers show an intensive study on the research the process of cutting off vacuum wiring, which includes improving process parameters that investigate the effect of various factors affecting the performance and productivity of machines. Selvakumar, Jiju, Brazil, Sarkar and Mitra **[2-3]** have the main objective of selecting the best combination of mechanical treatment for the manufacture of titanium wires. Prasad Arikatla, Tamil Mannan and Krishnaya**[4-6]** investigated the low effect of machine parameters on the cutting speed and rate of removal of materials for the manufacture of Nimonic 80A with

copper wire as a tool pole during the process of manufacturing electrical discharge by wire. The statistical analysis and regression of the slit width was proposed using the design of experiments by Parashar, Rehman, Bhagoria, and Puri**[7]** in their research work. Quadratic mathematical models were derived to represent the behavior of the process in electrical wiring. Operation of machines by Datta & Mahapatra, ND **[8-9]** and make the modern gradient of newer and more difficult material processing task in WEDM very difficult, so as to optimize the use of all resources. The present paper, focuses on wire **electric dis-charge machine** of titanium alloys. It can be considered as an attempt to develop two models of response variables, they are; the operating rate, the surface-roughness, and the rate of material removing, in the wire **electric dis-charge machine** process using the response surface methodology. The pilot plan is based on Minitab 18, and the analysis convey the major six parameters. A NOVA was applied to determine the importance of the advanced model, the test results confirm the validity and suitability of the advanced RSM-model. Lastly, the optimum parameter settings is improved.

PROPOSED EXPERIMENT SETTINGS

The current experiment is a pilot study where MRR and SR are being studied to evaluate the performance of the MRR, SR and Over Cut machines with input configurations such as:

- Feed rate wire,
- Wire tension,
- Pulse on time,
- Pulse stop time,
- Current voltage for peak and voltage range.

Electromagnetic Sprint cut-734 has been tested on the EDM system. Figure (1) illustrates the experimental setup used with the EDM CNC machine. The electrode wire was used in copper plated with 0.25 mm diameter and the deionized water was sterilized as the insulating fluid around the wire and lateral cleaning technique. We would like to point out that the previous indicators are in Table (1).

Figure 1: Four-Axis Electronic A Sprint Cut-734 CNC WEDM.

Table 1: Parameters and their Range

Number	Parameter	Specific Details	
1	On-time pulse	TON	105–130 mu
2	Off-time pulse	TOFF	36–60 mu
3	Peak-current	IP	40–230A
4	Spark-gap-set-voltage	SGSV	5–75V
5	Rate ofwire-feed	RWF	2–12 m/min
6	Tension of wire	TW	2–12 mu

Table 2: Chemical Compositions of Titanium Alloy (Ti-6242)

Elements	Al	Sn	Zr	Mo	Si	Fe	O2	C	N2	H2	Ti
% Maximum wt	6.0	2.0	4.0	2.0	0.13	0.25	0.15	0.08	0.05	0.0125	85.3

ANALYSIS OF NUMERICAL COMPUTATIONS

Table (3) shows the measured-values for MRR&SR responses, respectively, corresponds to BBD-design-matrix, also effects of process-parameters on MRR & SR had-been analysed by the response-surface and contour-plots.

Table 3: Design Matrix and Output Responses

Run Number	On-Time pulse	Off-Time Pulse	Peak-Current	Spark-gap-Voltage	Rate of Wire-Feed	Tension of Wire	Surface Roughness	MRR (mm^3/min)
1	1.1	28	200	50	7	500	3.22	9.6
2	0.9	38	160	50	4	500	2.48	4.92
3	0.7	28	160	60	4	950	2.23	3.39
4	0.9	17	120	50	10	950	2.75	8.29
5	0.9	28	120	60	7	500	2.47	4.45
6	1.1	28	160	40	4	950	2.93	9.2
7	0.9	38	160	50	10	1400	2.48	4.77
8	0.9	28	160	50	7	950	2.65	5.19
9	0.9	17	160	50	4	500	2.81	8.81
10	1.1	28	160	40	10	950	2.94	8.59
11	1.1	38	160	40	7	950	2.91	8.3
12	1.1	28	160	60	4	950	2.83	7.03
13	0.9	17	160	50	10	500	2.79	8.19
14	0.9	28	160	50	7	950	2.61	4.67
15	0.7	28	120	50	7	500	2.49	3.28
16	0.9	28	160	50	7	950	2.68	5.51
17	0.9	28	120	60	7	1400	2.49	4.66
18	0.7	38	160	40	7	950	2.32	3.65
19	0.9	38	120	50	10	950	2.31	4.37
20	0.9	28	200	40	7	1400	2.89	6.72
21	0.9	28	200	60	7	500	2.69	6.67
22	0.9	38	200	50	10	950	2.57	6.54
23	0.9	28	120	40	7	1400	2.71	5.07
24	0.7	28	120	50	7	1400	2.51	3.3
25	0.9	38	200	50	4	950	2.56	7.07
26	1.1	28	160	60	10	950	2.82	6.77
27	1.1	28	120	50	7	500	2.77	7.1
28	0.7	28	160	40	10	950	2.35	4.27
29	0.7	28	200	50	7	500	2.48	4.49
30	0.7	17	160	40	7	950	2.70	6.9
31	0.7	28	200	50	7	1400	2.51	4.44
32	0.9	28	160	50	7	950	2.65	4.7
33	0.9	17	200	50	4	950	2.88	8.06
34	0.9	28	160	50	7	950	2.65	5.61
35	1.1	17	160	40	7	950	3.28	11.16
36	0.9	17	200	50	10	950	2.98	8.28
37	0.9	28	200	40	7	500	2.84	7.07
38	0.7	28	160	40	4	950	2.33	4.41
39	0.9	38	160	50	10	500	2.50	4.96
40	0.9	28	160	50	7	950	2.69	5.65
41	1.1	38	160	60	7	950	2.66	6.77

42	0.7	17	160	60	7	950	2.60	4.14
43	0.9	28	200	60	7	1400	2.68	6.57
44	0.9	17	120	50	4	950	2.75	7.61
45	0.7	28	160	60	10	950	2.28	3.75
46	1.1	28	120	50	7	1400	2.75	7.11
47	0.7	38	160	60	7	950	2.15	3.28
48	0.9	17	160	50	4	1400	2.85	8.15
49	0.9	28	120	40	7	500	2.78	5.36
50	1.1	17	160	60	7	950	3.00	8.45
51	0.9	38	120	50	4	950	2.29	4.55
52	1.1	28	200	50	7	1400	3.12	8.37
53	0.9	17	160	50	10	1400	2.82	7.53
54	0.9	38	160	50	4	1400	2.49	4.92

MATERIAL REMOVAL RATE ANALYSIS

In the present paper, the MRR-Quadratic-Model was developed using Mini-tab 18, the ability of the model had been produced using ANOVA and tested at level of confidence - 95%, the results are given in table (4), as it is clear from table (4), one can prove that the F-value is 97.91 and the P-corresponding value < 0.0001, therefore, the squared-form is high at the level 95%, also, one can note that P will not be appropriate for the value > 0.05 (greater than 0.05), therefore, the deficiency of fitness is not-important, also, the deficiency of the fit-value of 0.475 has the meaning, it is not important for pure-error. In addition, the value of R_2 is 0.9457and shows 94.57% of the change in the MRR rate, due to the control-factors. Add to the previous result the expectation of R_2 at 0.9228 is acceptable compared with R_2 0.9360 that gives a high-correlation among the observed-values. Referring to Figure (2.1), which shows the normal-probability of MRR residues, also, it shows that errors are usually distributed. The observed-value for scheme are in figures (2.2-2.4), and they give the fact that the observed-response is very closer to the expected-values, and the model can determine the actual relation between process-parameters and outputs. From the computations one can conclude that the appropriate-resolution is 40.903 and this is suggests using a quadratic-model for navigation of R-design area. From the computation and analysis, one also conclude that the values of F and P that the factors A (TON) and B (TOFF) are the most important for MRR. The analysis leads to the fact that it can also be seen from the % age values of the input resulted for each source, determine how much of the parameter contributes to MRR.

Material Removal Rate

$$MRR = 22.086 + 10.2396 \times TON - 1.0095 \times TOFF - 0.0706 \times IP - 0.178 \times SV + 0.009 \times TOFF^2 + 0.00017 \times IP^2 + 0.0013 \times TOFF \times IP + 0.004 \times TOFF \times SV$$

Table 4: ANOVA for Response-Surface of Reduced-Quadratic-Model of Material-Removal-Rate

Sources	$\sum squares$	Freedom-degree	Mean-Square	F-value	$P > F$	Hint	%Cont
Models	180.930	08	022.62	97.91	< 0.0001	Significant	
A	100.660	1	100.66	435.74			52.61
B	041.270		041.27	178.64			21.57
C	014.620		014.62	63.28			7.64
D	009.090		009.09	39.35			4.75
B^2	11.35		11.35	49.12			5.93

C^2	0.98		0.98	4.24	0.0453		0.512
$B \times C$	2.26		2.26	9.77	0.0031		1.18
$B \times D$	1.59	1	1.59	6.90	0.0118		0.83
Residual	10.39	45	0.23				
Fit-lack	9.40	40	0.24	1.18	0.4750	Not significant	
Pure-Error	0.99	5	0.20				
Corrected Total	191.32	53					
Standard-Deviation Mean Coefficient of Variation PRESS	0.48 6.16 7.80 14.77	R^2 Adjusted R^2 Predicted R^2 Adequate Precision		0.9457 0.9360 0.9228 40.903			

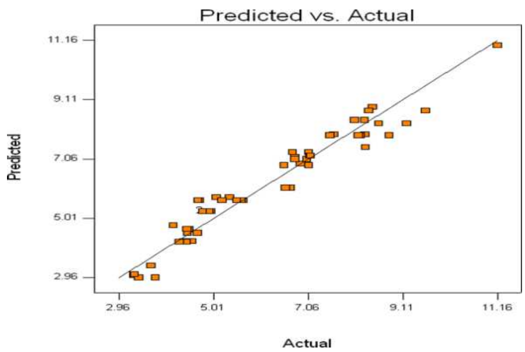

Figure (2.1): Actual-Versus Predicted of Metal-Removal-Rate.

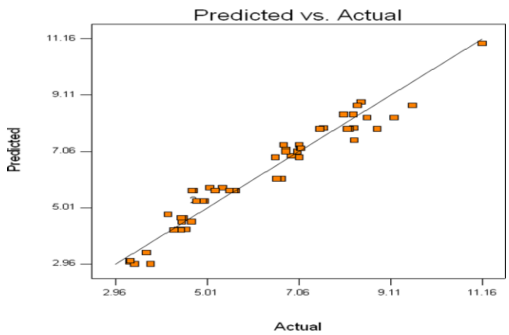

Figure (2.2): Actual Against Predicted of Metal-Removal-Rate.

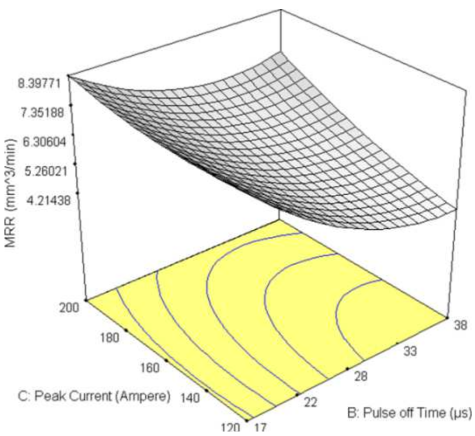

Figure 2.3: Inter-Action Among Pulse off-Time and Peak-Current.

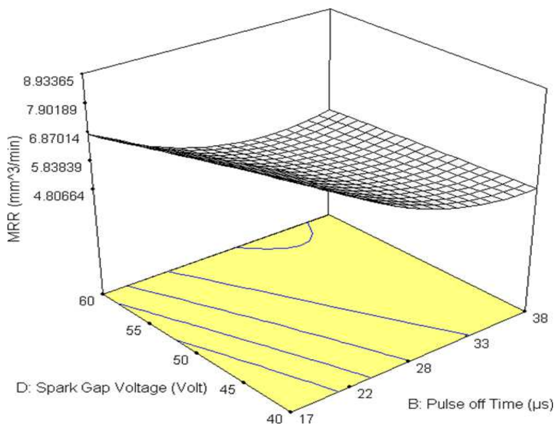

Figure 2.4: Interaction Among Pulse off-Time and Spark-Gap-Voltage.

Surface-Roughness: Analysis of the Model Tools

The roughness of the surface and its processing is one of the most important criteria for the process. In this process, the state of the surface to be formed is determined. As we have said, this process is the most important of these steps. It should be mentioned that if the surface finish of the work material is the most important and decisive factor, work materials should be classified at low material removal rates. The variance-analysis is given in table (5), during the preparation of the form, in-significant-terms are eliminated by default. Values of "Prob> F" below 0.05 indicate that the formation conditions are important at 95% confidence level. In addition to this normal piece of residue, the remaining

residues, as opposed to the forecast, were also drawn as shown in figures(3.1-3.3). Most residue falls on the other-hand straight-line, leading to errors that are distributed in a normal behavior. The results also proves that the regression-model is well-fitted with observed values. The results and charts shows that the expected and observed-values from the analysis is sufficient to determine the real-functional relation among input-parameters and surface-roughness. The model can be recognized as important for which is 145.26 and the p-value which is < 0.05, moreover, this means that there is 0.01% chance as the model F is a large-volume and may have occured due to noise. In MRR-case, there are too factors namely; A & B contribute nearly 83% of the total-variation in the response-data. After the surface-equation represents the specific relation among surface-roughness and process-coefficients.

The surface-equation responsible for determining the relation among surface-roughness and process-factors is obtained.

Surface Roughness 3.860 -0.767 × TON – 0.035 × TOFF - 0.009 × IP -0.009 × SV + 0.1247WF - 0.0004× WT + 0.0003 × TOFF2 - 0.009 × WF2 + 0.0000002 × WT2 + 0.013 × TON × IP

Table 5: ANOVA for Response Surface of the Reduced-Quadratic-Model

Sources	$\sum$ *squares*	Freedom-degree	**Mean-Square**	F-value	$P > F$	Hint	**% Cont.**
Models	3.08	10	0.31	145.26	<0.0001	significant	
A	1.64	1	1.64	775.10	<0.0001		55.0
B	0.84		0.84	396.22	<0.0001		28.0
C	0.23		0.23	108.54	<0.0001		8.0
D	0.18		0.18	85.03	<0.0001		6.0
B^2	0.013		0.013	6.36	0.0155		0.41
E^2	0.068		0.068	32.18	<0.0001		2.15
F^2	0.019		0.019	8.90	0.0047		0.6
$A \times F$	0.086		0.086	40.62	<0.0001		2.71
Residual	0.091	43	0.002120				
Lack of Fit	0.087	38	0.002295	2.91	0.1173	Not Significant	
Pure Error	0.003950	5	0.000790				
Corrected Total	3.17	53					
Standard Deviation 0.046 Mean 2.67 Coefficient of variation 1.73 PRESS 0.15				R2 0.9712 Adjusted R^2 0.9646 Predicted R^2 0.9527 Adequate Precision 51.529			

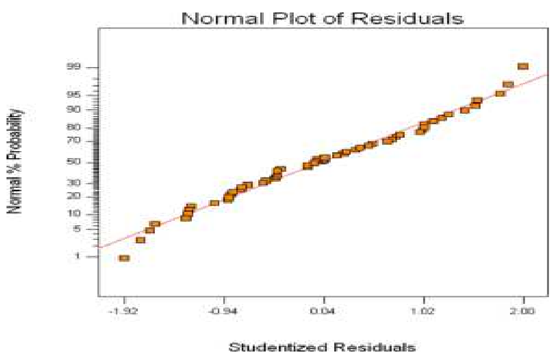

Figure 3.1: Normal-Prob for Residuals of Surface Roughness.

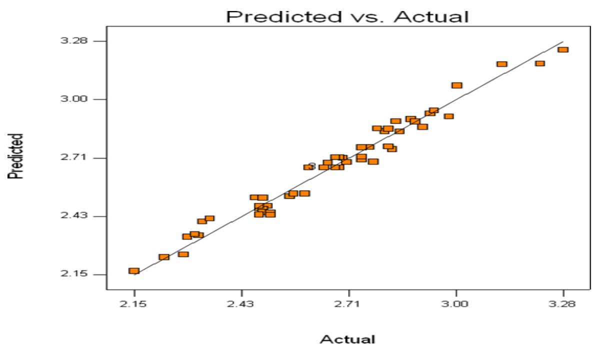

Figure 3.2:Actual Against Predicted of Surface-Roughness.

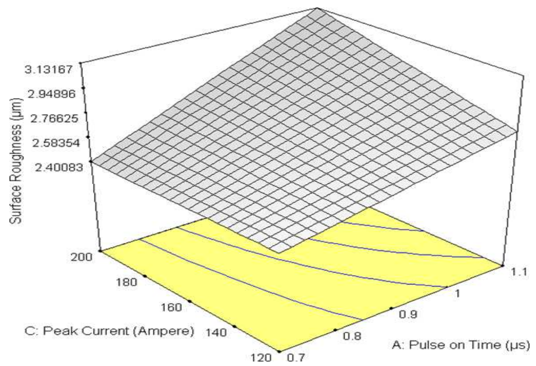

Figure 3.3: Interaction Against on-Time Pulse and Peak-Current.

CONCLUSIONS

From theoretical and experimental investigation, the following concluded remarks are obtained:

- The parameters of the ideal multi-objective process of responses were verified using final-confirmation experiments and results were found satisfactory.
- The error ratio among predictions of the optimize model and final-confirmation experiments was found to be approximately 4.11% for MR and nearly 2.99% for SR.
- The three-dimensional response surfaces and contour-lines showed that pulse on-Time plays a principle role as input-parameters and affects output-responses.
- For MRR & SR, on the other hand, three-dimensional response surfaces and contour-lines indicated by on Time pulse.
- Off-Time pulse, different results were obtained in different situations because these factors depend on the other hand-position.

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